

ABSTRACT

This final safety evaluation report documents the technical review of the AP1000 standard nuclear reactor design by the U.S. Nuclear Regulatory Commission (NRC). Westinghouse Electric Company submitted the application for the AP1000 design on March 28, 2002, in accordance with Title 10 of the Code of Federal Regulations (10 CFR) Part 52, Subpart B, "Standard Design Certifications," and 10 CFR Part 52, Appendix O, "Standardization of Design: Staff Review of Standard Designs."

The AP1000 nuclear reactor design is a pressurized water reactor with a power rating of 3415 megawatts thermal (MWt) and an electrical output of at least 1000 megawatts electric (MWe). The AP1000 design contains many features that are not found in current operating reactors. For example, a variety of engineering and operational improvements provide additional safety margins and address the Commission's severe accident, safety goal, and standardization policy statements. The most significant improvement to the design is the use of safety systems that employ passive means, such as gravity, natural circulation, condensation and evaporation, and stored energy, for accident mitigation. These passive safety systems perform safety injection, residual heat removal, and containment cooling functions.

Some features of the AP1000, compared to currently operating reactors, include a longer reactor core design, a larger pressurizer, an in-containment refueling water storage tank, an automatic depressurization system, a revised main control room design with a digital microprocessor-based instrumentation and control system, hermetically sealed canned reactor coolant pump motors mounted to the steam generator, and increased battery capacity. In addition, the facility is designed for a 60-year life, which exceeds the projected 40-year combined operating license period, and employs structural modules.

On the basis of its evaluation and independent analyses, as set forth in this report, the NRC staff concludes that Westinghouse's application for design certification meets the requirements of 10 CFR Part 52, Subpart B, that are applicable and technically relevant to the AP1000 standard design. Appendix G includes a copy of the report by the Advisory Committee on Reactor Safeguards, as required by 10 CFR 52.53.

TABLE OF CONTENTS

	<u>Page</u>
ABSTRACT	i
1. INTRODUCTION AND GENERAL DISCUSSION	1-1
1.1 Introduction	1-1
1.1.1 Metrication	1-2
1.1.2 Proprietary Information	1-2
1.1.3 Combined License Applicants Referencing the AP1000 Design	1-2
1.1.4 Additional Information	1-2
1.2 General Design Description	1-3
1.2.1 Scope of the AP1000 Design	1-3
1.2.2 Summary of the AP1000 Design	1-3
1.3 Comparison with Similar Facility Designs	1-13
1.4 Identification of Agents and Contractors	1-13
1.5 Summary of Principal Review Matters	1-14
1.6 Summary of Open Items	1-16
1.7 Summary of Confirmatory Items	1-16
1.8 Index of Exemptions	1-17
1.9 Index of Tier 2* Information	1-17
1.10 COL Action Items	1-18
2. SITE ENVELOPE	2-1
2.1 Geography and Demography	2-1
2.1.1 Site Location and Description	2-1
2.1.2 Exclusion Area Authority and Control	2-2
2.1.3 Population Distribution	2-2
2.2 Nearby Industrial, Transportation, and Military Facilities	2-2
2.3 Meteorology	2-3
2.3.1 Regional Climatology	2-3

	<u>Page</u>
2.3.2 Local Meteorology	2-4
2.3.3 Onsite Meteorological Measurements Program	2-4
2.3.4 Short-Term (Accident) Atmospheric Relative Concentration	2-4
2.3.5 Long-Term (Routine) Diffusion Estimates	2-5
2.4 Hydrologic Engineering	2-6
2.4.1 Hydrological Description	2-6
2.5 Geological, Seismological, and Geotechnical Engineering	2-7
2.5.1 Basic Geologic and Seismic Information	2-8
2.5.2 Vibratory Ground Motion	2-9
2.5.3 Surface Faulting	2-10
2.5.4 Stability of Subsurface Materials and Foundations	2-11
2.5.5 Stability of Slopes	2-15
2.5.6 Embankments and Dams	2-15
2.6 COL Action Items	2-16
3. DESIGN OF STRUCTURES, COMPONENTS, EQUIPMENT, AND SYSTEMS	3-1
3.1 General	3-1
3.2 Classification of Structures, Systems, and Components	3-1
3.2.1 Seismic Classification	3-1
3.2.2 Quality Group Classification	3-3
3.3 Wind and Tornado Loadings	3-6
3.3.1 Wind Design Criteria	3-6
3.3.2 Tornado Loading	3-9\
3.4 External and Internal Flooding	3-14
3.4.1 Flood Protection	3-14
3.5 Missile Protection	3-24
3.5.1 Missile Selection and Description	3-24
3.5.2 Protection From Externally Generated Missiles	3-35
3.5.3 Barrier Design Procedures	3-37

	<u>Page</u>
3.6 Protection against the Dynamic Effects Associated with the Postulated Rupture of Piping	3-38
3.6.1 Plant Design for Protection against Postulated Piping Failures in Fluid Systems Outside Containment	3-38
3.6.2 Determination of Rupture Locations and Dynamic Effects Associated with the Postulated Rupture of Piping	3-42
3.7 Seismic Design	3-63
3.7.1 Seismic Input	3-66
3.7.2 Seismic System Analysis	3-70
3.7.3 Seismic Subsystem Analysis	3-93
3.7.4 Seismic Instrumentation	3-96
3.7.5 Other Combined License Action Items	3-99
3.8 Design of Category I Structures	3-100
3.8.1 Concrete Containment	3-101
3.8.2 Steel Containment	3-101
3.8.3 Concrete and Steel Containment Internal Structures	3-123
3.8.4 Other Seismic Category I Structures	3-163
3.8.5 Foundations	3-191
3.8.6 Other Combined License Action Items	3-203
3.9 Mechanical Systems and Components	3-204
3.9.1 Special Topics for Mechanical Components	3-204
3.9.2 Dynamic Testing and Analysis of Systems, Components, and Equipment	3-207
3.9.3 ASME Code Class 1, 2, and 3 Components, Component Supports, and Core Support Structures	3-219
3.9.4 Control Rod Drive Systems	3-230
3.9.5 Reactor Pressure Vessel Internals	3-233
3.9.6 Testing of Pumps and Valves	3-238
3.9.7 Integrated Head Package	3-242
3.9.8 Other Combined License Action Items	3-244
3.10 Seismic and Dynamic Qualification of Seismic Category I Mechanical and Electrical Equipment	3-244
3.10.1 Conclusions	3-248
3.11 Environmental Qualification of Mechanical and Electrical Equipment	3-249
3.11.1 Introduction	3-249

	<u>Page</u>
3.11.2 Regulatory Evaluation	3-249
3.11.3 Technical Evaluation	3-251
3.12 Piping Design	3-254
3.12.1 Introduction	3-254
3.12.2 Codes and Standards	3-255
3.12.3 Piping Analysis Methods	3-257
3.12.4 Piping Modeling Techniques	3-263
3.12.5 Piping Stress Analysis Criteria	3-268
3.12.6 Pipe Support Design Criteria	3-287
4. REACTOR	4-1
4.1 Introduction	4-1
4.2 Fuel System Design	4-1
4.2.1 Fuel Assembly Description	4-2
4.2.2 Fuel Rod Description	4-3
4.2.3 Burnable Absorber Assembly Description	4-4
4.2.4 Rod Cluster Control Assembly/Gray Rod Cluster Assembly Description	4-4
4.2.5 Design Basis	4-4
4.2.6 Design Evaluation	4-5
4.2.7 Testing and Inspection Plan	4-7
4.2.8 Conclusion	4-7
4.3 Nuclear Design	4-8
4.3.1 Design Basis	4-8
4.3.2 Description	4-9
4.3.3 Analytical Methods	4-13
4.3.4 Summary of Evaluation Findings	4-14
4.4 Thermal-Hydraulic Design	4-16
4.4.1 Thermal-Hydraulic Design Bases	4-16
4.4.2 Thermal-Hydraulic Design of the Reactor Core	4-20
4.4.3 Testing and Verification	4-24
4.4.4 Instrumentation Requirements	4-24
4.4.5 Conclusions and Summary	4-26
4.5 Reactor Materials	4-26
4.5.1 Control Rod Drive System Structural Materials	4-26

	<u>Page</u>
4.5.2 Reactor Internal and Core Support Materials	4-33
4.6 Functional Design of Reactivity Control Systems	4-37
5. REACTOR COOLANT SYSTEM AND CONNECTED SYSTEMS	5-1
5.1 Summary Description	5-1
5.1.1 Design Bases	5-1
5.1.2 Design Description	5-2
5.1.3 System Components	5-4
5.1.4 System Performance Characteristics	5-6
5.2 Integrity of Reactor Coolant Pressure Boundary	5-8
5.2.1 Compliance With Code and Code Cases	5-8
5.2.2 Overpressure Protection	5-11
5.2.3 Reactor Coolant Pressure Boundary Materials	5-16
5.2.4 RCS Pressure Boundary Inservice Inspection and Testing	5-26
5.2.5 Reactor Coolant Pressure Boundary Leakage Detection	5-30
5.3 Reactor Vessel	5-36
5.3.1 Reactor Vessel Design	5-36
5.3.2 Reactor Vessel Materials	5-37
5.3.3 Pressure-Temperature Limits	5-43
5.3.4 Pressurized Thermal Shock	5-49
5.3.5 Reactor Vessel Integrity	5-50
5.4 Component and Subsystem Design	5-54
5.4.1 Reactor Coolant Pump Assembly	5-54
5.4.2 Steam Generators	5-61
5.4.3 RCS Piping	5-74
5.4.4 Main Steamline Flow Restriction	5-76
5.4.5 Pressurizer	5-77
5.4.6 Automatic Depressurization System Valves	5-78
5.4.7 Normal Residual Heat Removal System	5-79
5.4.8 Valves	5-88
5.4.9 Reactor Coolant System Pressure Relief Devices	5-88
5.4.10 RCS Component Supports	5-90
5.4.11 Pressurizer Relief Discharge	5-90
5.4.12 Reactor Coolant System High-Point Vents	5-93
5.4.13 Core Makeup Tank	5-96
5.4.14 Passive Residual Heat Removal Heat Exchanger	5-98

	<u>Page</u>
6. ENGINEERED SAFETY FEATURES	6-1
6.1 Engineered Safety Features Materials	6-1
6.1.1 Structural Materials	6-1
6.1.2 Protective Coating Systems (Paints)—Organic Materials	6-7
6.2 Containment Systems	6-9
6.2.1 Primary Containment Functional Design	6-10
6.2.2 Containment Heat Removal Systems	6-54
6.2.3 Shield Building Functional Design	6-56
6.2.4 Containment Isolation System	6-56
6.2.5 Containment Combustible Gas Control	6-64
6.2.6 Containment Leakage Testing	6-71
6.2.7 Fracture Prevention of Containment Pressure Boundary	6-77
6.2.8 In-Containment Refueling Water Storage Tank Hydrodynamic Loads	6-78
6.3 Passive Core Cooling System	6-79
6.3.1 Design Bases	6-82
6.3.2 System Design	6-84
6.3.3 Performance Evaluation	6-94
6.3.4 Post-72 Hour Actions	6-96
6.3.5 Limits on System Parameters	6-97
6.3.6 Conclusions	6-97
6.4 Control Room Habitability Systems	6-98
6.5 Fission Product Removal and Control Systems	6-110
6.5.1 ESF Plant Atmosphere Filtration Systems	6-110
6.5.2 Containment Spray System	6-110
6.5.3 Fission Product Control Systems	6-110
6.6 Inservice Inspection of Class 2 and 3 Components	6-111
7. INSTRUMENTATION AND CONTROLS	7-1
7.1 Introduction	7-1
7.1.1 Acceptance Criteria	7-1
7.1.2 Basis and Method of Review	7-4
7.1.3 General Findings	7-5
7.1.4 Tier 1, Material	7-7

	<u>Page</u>
7.1.5 Instrumentation & Control System Architecture	7-8
7.1.6 Defense-in-Depth and Diversity Assessment of the AP1000 Protection System	7-9
7.1.7 Commercial-Grade Item Dedication	7-12
7.2 Reactor Trip System	7-13
7.2.1 System Description	7-13
7.2.2 Protection and Safety Monitoring System Description	7-15
7.2.3 Common Qualified Platform Design and COL Action Items	7-17
7.2.4 Resolution of Common Qualified Platform Generic Open Items	7-20
7.2.5 PMS Design Process Review	7-21
7.2.6 Protection Systems Test Intervals and Allowed Outage Time	7-23
7.2.7 Protection Systems Setpoint Methodology	7-24
7.2.8 PMS Evaluation Findings and Conclusions	7-24
7.3 Engineered Safety Features Actuation Systems	7-35
7.3.1 System Description	7-35
7.3.2 Blocks, Permissives, and Interlocks for Engineered Safety Features Actuation	7-44
7.3.3 Essential Auxiliary Supporting Systems	7-46
7.3.4 ESFAS Evaluation Findings and Conclusions	7-47
7.4 Systems Required for Safe Shutdown	7-48
7.4.1 System Description	7-48
7.4.2 Safe Shutdown from Outside the Main Control Room	7-49
7.4.3 Evaluation Findings and Conclusions	7-50
7.5 Safety-Related Display Information	7-51
7.5.1 System Description	7-51
7.5.2 Processing and Display Equipment	7-53
7.5.3 Network Gateway (Real-Time to PMS)	7-53
7.5.4 Operation and Control Centers System	7-54
7.5.5 Qualified Data Processing System	7-55
7.5.6 Bypass and Inoperable Status Information	7-56
7.5.7 In-Core Instrumentation System	7-57
7.5.8 Special Monitoring System	7-58
7.5.9 Evaluation Findings and Conclusions	7-58
7.6 Interlock Systems Important to Safety	7-59
7.6.1 Normal Residual Heat Removal System Isolation Valves	7-59

	<u>Page</u>
7.6.2 Interlocks for the Accumulator Isolation Valve and IRWST Discharge Valve	7-60
7.6.3 Core Makeup Tank Cold-Leg Balance Line Isolation Valves	7-60
7.6.4 PRHR Heat Exchanger Inlet Isolation Valve	7-61
7.6.5 Evaluation Findings and Conclusions	7-62
7.7 Control and Instrumentation Systems	7-63
7.7.1 System Description	7-63
7.7.2 Diverse Actuation System	7-67
7.7.3 Signal Selector Algorithms	7-70
7.7.4 Evaluation Findings and Conclusions	7-70
8. ELECTRIC POWER SYSTEMS	8-1
8.1 Introduction	8-1
8.2 Offsite Power System	8-1
8.2.1 Offsite Circuits Outside the AP1000 Scope of Design	8-2
8.2.2 Offsite Circuits within the AP1000 Scope of Design	8-2
8.2.3 Offsite Power System Interfaces	8-2
8.3 Onsite Power Systems	8-7
8.3.1 AC Onsite Power System	8-7
8.3.2 Direct Current Power and Uninterruptible Power Systems	8-15
8.4 Other Electrical Features and Requirements for Safety	8-25
8.4.1 Containment Electrical Penetrations	8-25
8.4.2 Reactor Coolant Pump Breakers	8-26
8.4.3 Thermal Overload Protection Bypass	8-26
8.4.4 Power Lockout to Motor-Operated Valves	8-27
8.4.5 Submerged Class 1E Electrical Equipment as a Result of a Loss-of- Coolant Accident	8-27
8.5 Compliance with Regulatory Issues	8-28
8.5.1 Generic Issues and Operational Experience	8-28
8.5.2 Advanced Light-Water Reactor Certification Issues	8-29

	<u>Page</u>
9. AUXILIARY SYSTEMS	9-1
9.1 Fuel Storage and Handling	9-1
9.1.1 New Fuel Storage	9-1
9.1.2 Spent Fuel Storage	9-3
9.1.3 Spent Fuel Pool Cooling and Purification	9-6
9.1.4 Light-Load Handling System (Related to Refueling)	9-11
9.1.5 Overhead Heavy-Load Handling Systems	9-13
9.1.6 Combined License Information Items	9-15
9.2 Water Systems	9-16
9.2.1 Service Water System	9-16
9.2.2 Component Cooling Water System	9-19
9.2.3 Demineralized Water Treatment System	9-20
9.2.4 Demineralized Water Transfer and Storage System	9-21
9.2.5 Potable Water System	9-22
9.2.6 Sanitary Drainage System	9-23
9.2.7 Central Chilled Water System	9-24
9.2.8 Turbine Building Closed-Cooling System	9-26
9.2.9 Waste Water System	9-26
9.2.10 Hot Water Heating System	9-27
9.3 Process Auxiliaries	9-29
9.3.1 Compressed and Instrument Air System	9-29
9.3.2 Plant Gas System	9-32
9.3.3 Primary Sampling System	9-32
9.3.4 Secondary Sampling System	9-34
9.3.5 Equipment and Floor Drainage System	9-36
9.3.6 Chemical and Volume Control System	9-38
9.4 Air Conditioning, Heating, Cooling, and Ventilation System	9-41
9.4.1 Nuclear Island Nonradioactive Ventilation System	9-42
9.4.2 Annex/Auxiliary Buildings Nonradioactive HVAC System	9-53
9.4.3 Radiologically Controlled Area Ventilation System	9-60
9.4.4 Balance-of-Plant Interfaces	9-66
9.4.5 Engineered Safety Features Ventilation System	9-66
9.4.6 Containment Recirculation Cooling System	9-67
9.4.7 Containment Air Filtration System	9-70
9.4.8 Radwaste Building HVAC System	9-75
9.4.9 Turbine Building Ventilation System	9-77
9.4.10 Diesel Generator Building Heating and Ventilation System	9-80
9.4.11 Health Physics and Hot Machine Shop HVAC System	9-83

	<u>Page</u>
9.5 Other Auxiliary Systems	9-87
9.5.1 Fire Protection Program	9-87
9.5.2 Communication Systems	9-114
9.5.3 Plant Lighting System	9-118
9.5.4 Standby Diesel Generator Auxiliary Support Systems	9-120
9.5.5 Standby Diesel Generator Cooling System	9-121
9.5.6 Standby Diesel Generator Starting System	9-121
9.5.7 Standby Diesel Generator Lubricating Oil System	9-122
9.5.8 Standby Diesel Generator Combustion Air Intake and Exhaust System	9-122
9.5.9 Diesel Generator and Auxiliary Boiler Fuel Oil System	9-123
10. STEAM AND POWER CONVERSION SYSTEM	10-1
10.1 Introduction	10-1
10.2 Turbine Generator	10-2
10.2.1 Overspeed Protection	10-2
10.2.2 Digital Electrohydraulic Control System	10-3
10.2.3 Automatic Turbine Control	10-3
10.2.4 Turbine Protective Trips	10-3
10.2.5 Valve Control	10-4
10.2.6 Turbine Missiles	10-5
10.2.7 Access to Turbine Areas	10-5
10.2.8 Turbine Rotor Integrity	10-6
10.2.9 Conclusions	10-11
10.3 Main Steam Supply System	10-11
10.3.1 Main Steam Supply System Design	10-11
10.3.2 Steam and Feedwater System Materials	10-16
10.4 Other Features	10-19
10.4.1 Main Condenser	10-19
10.4.2 Main Condenser Evacuation System	10-21
10.4.3 Turbine Gland Seal System	10-23
10.4.4 Turbine Bypass System	10-24
10.4.5 Circulating Water System	10-26
10.4.6 Condensate Polishing System	10-29
10.4.7 Condensate and Feedwater System	10-30
10.4.8 Steam Generator Blowdown System	10-34
10.4.9 Startup Feedwater System	10-36
10.4.10 Auxiliary Steam System	10-39

	<u>Page</u>
10.5 Combined License Action Items	10-40
11. RADIOACTIVE WASTE MANAGEMENT	11-1
11.1 Source Terms	11-1
11.2 Liquid Waste Management System	11-5
11.2.1 System Description and Review Discussion	11-5
11.2.2 Conclusion	11-12
11.3 Gaseous Waste Management System	11-13
11.3.1 System Description and Review Discussion	11-13
11.3.2 Conclusions	11-19
11.4 Solid Waste Management System	11-19
11.4.1 System Description and Review Discussion	11-19
11.4.2 Conclusion	11-26
11.5 Process and Effluent Radiological Monitoring and Sampling System	11-26
11.5.1 System Description and Review Discussion	11-26
11.5.2 Conclusions	11-35
12. RADIATION PROTECTION	12-1
12.1 Introduction	12-1
12.2 Ensuring That Occupational Radiation Doses Are As Low As Is Reasonably Achievable	12-2
12.2.1 Policy Considerations	12-2
12.2.2 Design Considerations	12-3
12.2.3 Operational Considerations	12-5
12.2.4 Conclusion	12-6
12.3 Radiation Sources	12-6
12.3.1 Contained Sources	12-6
12.3.2 Airborne Radioactive Material Sources	12-8
12.3.3 Conclusion	12-8

	<u>Page</u>
12.4 Radiation Protection Design	12-8
12.4.1 Facility Design Features	12-9
12.4.2 Shielding	12-12
12.4.3 Ventilation	12-13
12.4.4 Area Radiation and Airborne Radioactivity Monitoring Instrumentation	12-15
12.4.5 Conclusion	12-17
12.5 Dose Assessment	12-17
12.6 Health Physics Facilities Design	12-19
13. CONDUCT OF OPERATIONS	13-1
13.1 Organizational Structure of the Applicant	13-1
13.2 Training	13-1
13.3 Emergency Planning	13-1
13.3.1 Introduction	13-1
13.3.2 Emergency Planning Responsibilities	13-2
13.3.3 TSC/OSC/Decontamination Facility	13-3
13.3.4 Overall Emergency Planning Findings	13-25
13.4 Operational Review	13-26
13.5 Plant Procedures	13-26
13.6 Security	13-26
13.6.1 Preliminary Planning	13-27
13.6.2 Security Plan	13-27
13.6.3 Plant Protection System	13-28
13.6.4 Physical Security Organization	13-29
13.6.5 Physical Barriers	13-29
13.6.6 Access Requirements	13-31
13.6.7 Detection Aids	13-31
13.6.8 Security Lighting	13-31
13.6.9 Security Power Supply System	13-32
13.6.10 Communications	13-32
13.6.11 Testing and Maintenance	13-32
13.6.12 Response Requirements	13-33
13.6.13 Combined License Information Items	13-33

	<u>Page</u>
14. VERIFICATION PROGRAMS	14-1
14.1 Preliminary Safety Analysis Report Information	14-1
14.2 Initial Plant Test Program	14-1
14.2.1 Introduction	14-1
14.2.2 Organization and Staffing	14-4
14.2.3 Test Procedures	14-4
14.2.4 Review, Evaluation, and Approval of Test Results	14-5
14.2.5 Utilization of Reactor Operating and Testing Experiences in the Development of the Test Program	14-5
14.2.6 Trial Use of Plant Operating and Emergency Procedures	14-8
14.2.7 Conformance of Test Programs with Regulatory Guides	14-9
14.2.8 Test Program Schedule and Sequence	14-15
14.2.9 Preoperational Test Abstracts	14-15
14.2.10 Initial Fuel Loading, Initial Criticality, Startup, and Power Ascension Tests	14-25
14.2.11 Conclusions	14-42
14.3 Tier 1 Information	14-42
14.3.1 Introduction	14-42
14.3.2 Inspection, Test, Analyses, and Acceptance Criteria	14-43
14.3.3 Design Acceptance Criteria	14-57
14.3.4 Other Tier 1 Information	14-67
14.4 Combined License Applicant Responsibilities	14-68
15. TRANSIENT AND ACCIDENT ANALYSES	15-1
15.1 Introduction	15-1
15.1.1 Event Categorization	15-1
15.1.2 Non-Safety-Related Systems Assumed in the Analysis	15-2
15.1.3 Chapter 15 Loss of Offsite Power Assumptions	15-4
15.1.4 Analytical Methods	15-5
15.1.5 Steam Generator Middeck Plate Induced Level Measurement Uncertainty	15-8
15.2 Transient and Accident Analysis	15-10
15.2.1 Increase in Heat Removal from the Primary System	15-10
15.2.2 Decrease in Heat Removal by the Secondary System (DCD Tier 2, Section 15.2)	15-17

	<u>Page</u>
15.2.3 Decrease in Reactor Coolant System Flow Rate (DCD Tier 2, Section 15.3)	15-24
15.2.4 Reactivity and Power Distribution Anomalies (DCD Tier 2, Section 15.4)	15-27
15.2.5 Increase in Reactor Coolant System Inventory (DCD Tier 2, Section 15.5)	15-37
15.2.6 Decrease in Reactor Coolant Inventory (DCD Tier 2, Section 15.6)	15-39
15.2.7 Post-LOCA Long-Term Cooling (DCD Tier 2, Section 15.6.5.4C) .	15-51
15.2.8 Deboration during SBLOCAs	15-61
15.2.9 Anticipated Transients Without Scram (DCD Tier 2, Section 15.8)	15-63
15.2.10 Conclusions	15-65
 15.3 Radiological Consequences of Accidents	 15-66
15.3.1 Radiological Consequences of a Main Steam Line Break Outside Containment	15-70
15.3.2 Radiological Consequences of a Reactor Primary Coolant Pump Seizure (Locked Rotor)	15-72
15.3.3 Radiological Consequences of Rod Cluster Control Assembly Ejection	15-73
15.3.4 Radiological Consequences of the Failure of Small Lines Carrying Primary Coolant Outside Containment	15-75
15.3.5 Radiological Consequences of a Steam Generator Tube Rupture .	15-77
15.3.6 Radiological Consequences of LOCAs	15-78
15.3.7 Radiological Consequences of a Fuel-Handling Accident	15-85
15.3.8 Offsite Radiological Consequences of Liquid Tank Failure	15-87
15.3.9 Radiological Consequences of Loss of Spent Fuel Pool Cooling . .	15-87
15.3.10 Conclusions	15-88
 16. TECHNICAL SPECIFICATIONS	 16-1
16.1 Introduction	16-1
16.2 Evaluation	16-1
16.2.1 AP1000 TS Section 1.0, "Use and Application"	16-2
16.2.2 AP1000 TS Section 2.0, "Safety Limits"	16-3
16.2.3 AP1000 TS Section 3.0, "Limiting Condition for Operation Applicability and Surveillance Requirement Applicability"	16-3
16.2.4 AP1000 TS Section 3.1, "Reactivity Control Systems"	16-3
16.2.5 AP1000 TS Section 3.2, "Power Distribution Limits"	16-3
16.2.6 AP1000 TS Section 3.3, "Instrumentation"	16-4
16.2.7 AP1000 TS Section 3.4, "Reactor Coolant System"	16-6
16.2.8 AP1000 TS Section 3.5, "Passive Core Cooling System"	16-9

	<u>Page</u>
16.2.9 AP1000 TS Section 3.6, "Containment Systems"	16-14
16.2.10 AP1000 TS Section 3.7, "Plant Systems"	16-16
16.2.11 AP1000 TS Section 3.8, "Electrical Power Systems"	16-20
16.2.12 AP1000 TS Section 3.9, "Refueling Operations"	16-21
16.2.13 AP1000 Shutdown Operations	16-23
16.2.14 AP1000 TS Section 4.0, "Design Features"	16-23
16.2.15 AP1000 TS Section 5.0, "Administrative Controls"	16-23
16.3 Conclusions	16-23
17. QUALITY ASSURANCE	17-1
17.1 Quality Assurance During the Design and Construction Phase	17-1
17.2 Quality Assurance During the Operations Phase	17-1
17.3 Quality Assurance During the Design Phase	17-1
17.3.1 General	17-1
17.3.2 Evaluation	17-2
17.3.3 Conclusions	17-9
17.4 Reliability Assurance Program During the Design Phase	17-9
17.4.1 General	17-10
17.4.2 Scope	17-11
17.4.3 Design Considerations	17-12
17.4.4 Relationship to Other Administrative Programs	17-12
17.4.5 The AP1000 Design Organization	17-13
17.4.6 Objective	17-14
17.4.7 D-RAP Phases	17-15
17.4.8 Glossary of Terms	17-22
17.4.9 Conclusions	17-23
17.5 Combined License Information Items	17-23
18. HUMAN FACTORS ENGINEERING	18-1
18.1 Review Methodology	18-1
18.1.1 Human Factors Engineering Review Objective	18-1
18.1.2 Review Criteria	18-2
18.1.3 Procedure for Reviewing AP1000 Human Factors Engineering	18-2

	<u>Page</u>
18.2 Element 1: Human Factors Engineering Program Management	18-4
18.2.1 Objectives	18-4
18.2.2 Methodology	18-4
18.2.3 Results	18-6
18.2.4 Conclusions	18-20
18.3 Element 2: Operating Experience Review	18-20
18.3.1 Objective	18-20
18.3.2 Methodology	18-20
18.3.3 Results	18-20
18.3.4 Conclusions	18-26
18.4 Element 3: Functional Requirements Analysis and Function Allocation	18-27
18.4.1 Objectives	18-27
18.4.2 Methodology	18-27
18.4.3 Results	18-27
18.4.4 Conclusions	18-34
18.5 Element 4: Task Analysis	18-34
18.5.1 Objectives	18-34
18.5.2 Methodology	18-34
18.5.3 Results	18-35
18.5.4 Conclusions	18-39
18.6 Element 5: Staffing and Qualifications	18-39
18.6.1 Objectives	18-39
18.6.2 Methodology	18-40
18.6.3 Results	18-40
18.6.4 Conclusions	18-43
18.7 Element 6: Human Reliability Analysis	18-43
18.7.1 Objectives	18-43
18.7.2 Methodology	18-44
18.7.3 Results	18-44
18.7.4 Conclusions	18-49
18.8 Element 7: Human-System Interface Design	18-50
18.8.1 HSI Design Process	18-50
18.8.2 Safety Parameter Display System	18-58

	<u>Page</u>
18.9 Element 8: Procedure Development	18-65
18.9.1 Objectives	18-65
18.9.2 Methodology	18-66
18.9.3 Results	18-66
18.9.4 Conclusions	18-68
18.10 Element 9: Training Program Development	18-69
18.10.1 Objectives	18-69
18.10.2 Methodology	18-69
18.10.3 Results	18-70
18.10.4 Conclusions	18-70
18.11 Element 10: Human Factors Verification and Validation	18-70
18.11.1 Objectives	18-70
18.11.2 Methodology	18-71
18.11.3 Results	18-71
18.11.4 Conclusions	18-84
18.12 Element 11: Design Implementation	18-85
18.12.1 Objectives	18-85
18.12.2 Methodology	18-85
18.12.3 Results	18-85
18.12.4 Conclusions	18-85
18.13 Element 12: Human Performance Monitoring	18-86
18.13.1 Objectives	18-86
18.13.2 Methodology	18-86
18.13.3 Results	18-86
18.13.4 Conclusions	18-86
18.14 Element 13: Minimum Inventory	18-86
18.14.1 Objectives	18-87
18.14.2 Methodology	18-87
18.14.3 Results	18-87
18.14.4 Conclusions	18-96
18.15 Summary and Conclusions	18-96
18.16 Tier 2* Information:	18-96

	<u>Page</u>
19. SEVERE ACCIDENTS	19-1
19.1 Probabilistic Risk Assessment	19-8
19.1.1 Introduction	19-8
19.1.2 Special Advanced Design Features	19-11
19.1.3 Safety Insights from the Internal Events Risk Analysis (Operation at Power)	19-20
19.1.4 Safety Insights from the Internal Events Risk Analysis for Shutdown Operation	19-63
19.1.5 Safety Insights from the External Events Risk Analysis	19-75
19.1.6 Use of PRA in the Design Process	19-96
19.1.7 PRA Input to the Regulatory Treatment of Non-Safety-Related Systems Process	19-98
19.1.8 PRA Input to the Design Certification Process	19-101
19.1.9 Conclusions and Findings	19-125
19.1.10 Resolution of DSER Open Items	19-126
19.2 Severe Accident Performance	19-137
19.2.1 Introduction	19-137
19.2.2 Deterministic Assessment of Severe Accident Prevention	19-138
19.2.3 Deterministic Assessment of Severe Accident Mitigation	19-142
19.2.4 Containment Performance Goal	19-183
19.2.5 Accident Management	19-186
19.3 Shutdown Evaluation	19-194
19.3.1 Introduction	19-194
19.3.2 Design Features that Minimize Shutdown Risk	19-195
19.3.3 Temporary RCS Boundaries	19-200
19.3.4 Instrumentation and Control during Shutdown Operations (DCD Tier 2, Section 19E.2.1.2.2)	19-202
19.3.5 Technical Specifications (DCD Tier 2, Section 19E.5)	19-204
19.3.6 Transient and Accident Analysis (DCD Tier 2, Section 19E.4) ...	19-206
19.3.7 Outage Planning and Control	19-220
19.3.8 Fire Protection	19-221
19.3.9 Operator Training and Emergency Response Guidelines (DCD Tier 2, Section 19E.3.3)	19-223
19.3.10 Flood Protection	19-224
19.4 Consideration of Potential Design Improvements Under Requirements of 10 CFR 50.34(f)	19-227
19.4.1 Introduction	19-227
19.4.2 Estimate of Risk for the AP1000	19-227

	<u>Page</u>
19.4.3 Identification of Potential Design Improvements	19-229
19.4.4 Risk Reduction Potential of Design Improvements	19-235
19.4.5 Cost Impacts of Candidate Design Improvements	19-235
19.4.6 Cost-Benefit Comparison	19-236
19.4.7 Conclusions	19-240
19A. SEISMIC MARGIN ANALYSIS	19A-1
19A.1 Seismic Margin HCLPF Methodology	19A-1
19A.2 Calculation of HCLPF Values	19A-1
19A.3 Seismic Margin Model	19A-11
19A.4 Calculation of Plant HCLPF	19A-14
19A.5 Conclusions	19A-15
20. GENERIC ISSUES	20-1
20.1 Overview of Staff Conclusions	20-1
20.1.1 Compliance with 10 CFR 52.47(a)(1)(iv)	20-1
20.1.2 Compliance with 10 CFR 52.47(a)(1)(ii)	20-2
20.1.3 Incorporation of Operating Experience	20-2
20.1.4 Resolution of Issues Relevant to the AP1000 Design	20-2
20.2 Task Action Plan Items	20-8
20.3 New Generic Issues	20-33
20.4 Three Mile Island Action Items	20-68
20.5 Human Factors Issues	20-108
20.6 Three Mile Island Action Plan Requirements	20-111
20.7 Incorporation of Operating Experience	20-112
20.7.1 Background	20-112
20.7.2 Application Content Review	20-113
20.7.4 Conclusions	20-114

	<u>Page</u>
21. TESTING AND COMPUTER CODE EVALUATION	21-1
21.1 Introduction	21-1
21.1.1 Passive Emergency Injection Systems	21-3
21.1.2 Ultimate Heat Sink	21-3
21.1.3 Passive Residual Heat Removal System	21-3
21.1.4 Automatic Depressurization System	21-3
21.1.5 Unique Characteristics of the Passive Design	21-4
21.2 Issues of Concern	21-5
21.2.1 Core Makeup Tanks	21-6
21.2.2 Automatic Depressurization System	21-6
21.2.3 Passive Residual Heat Removal System	21-7
21.2.4 Interdependency of Systems	21-7
21.2.5 Application of Existing Models and Correlations	21-8
21.2.6 Summary	21-9
21.3 Overview of Westinghouse Testing Programs	21-9
21.3.1 Core Makeup Tank Test Program	21-10
21.3.2 Automatic Depressurization System Test Program	21-11
21.3.3 Passive Residual Heat Removal Heat Exchanger Test Program ..	21-13
21.3.4 Oregon State University/Advanced Plant Experiment (APEX-600) Test Program	21-14
21.3.5 SPES-2 High-Pressure, Full-Height Integral-Systems Test Program	21-15
21.3.6 OSU APEX-1000 Test Program	21-17
21.3.7 Wind Tunnel Test Program	21-19
21.3.8 Large-Scale Passive Containment Cooling System Test Program ..	21-25
21.3.9 Water Distribution Testing Program	21-31
21.4 Overview of NRC Activities on the Test Programs	21-34
21.4.1 Wind Tunnel Test Programs	21-35
21.4.2 Large-Scale PCS Test Program	21-35
21.4.3 Water Distribution Test Program	21-38
21.5 Evaluation of Vendor Testing Programs	21-38
21.5.1 Phenomena Identification and Ranking Tables	21-39
21.5.2 Core Makeup Tank Test Program	21-41
21.5.3 Automatic Depressurization System Test Program	21-42
21.5.4 Passive Residual Heat Removal Heat Exchanger Test Program ..	21-44

	<u>Page</u>
21.5.5 Oregon State University/Advanced Plant Experiment (APEX-600) Test Program	21-46
21.5.6 SPES-2 High-Pressure, Full-Height Integral Systems Test Program	21-48
21.5.7 Scaling Analysis for Application of AP600 Integral Effects Tests to AP1000	21-50
21.5.8 APEX-1000 Test Program	21-64
21.5.9 Wind Tunnel Test Programs	21-69
21.5.10 PCS Test Program	21-72
21.5.11 Water Distribution Test Program	21-78
21.5.12 Compliance With 10 CFR 52.47(b)(2)	21-79
 21.6 Assessment of Analysis Codes	 21-80
21.6.1 LOFTRAN/LOFTTR2 Computer Code for non-LOCA Transients ..	21-81
21.6.2 NOTRUMP Computer Code for Small-Break LOCAs	21-85
21.6.3 WCOBRA/TRAC for Large-Break LOCA Analyses	21-101
21.6.4 WCOBRA/TRAC for Long-Term Cooling	21-107
21.6.5 WGOTHIC Computer Program for Containment DBA Analysis ..	21-110
 21.7 Quality Assurance Inspections	 21-255
 Appendix 21.A Safety Evaluation of AP600 Best-Estimate Large-Break LOCA Analysis Methodology	 21.A-1
21.A.1 Westinghouse Methodology and Comparison to the CSAU Methodology	21.A-1
21.A.1.1 Element 1 - Requirements and Capabilities	21.A-1
21.A.1.2 Element 2 - Assessment and Ranging of Parameters	21.A-4
21.A.1.3 Element 3 - Sensitivity and Uncertainty Analysis	21.A-7
21.A.1.4 Summary of Review	21.A-9
21.A.2 PIRT Evaluations (CSAU Step 3)	21.A-10
21.A.3 Code Assessment (CSAU Step 7)	21.A-12
21.A.3.1 Summary of Westinghouse WCOBRA/TRAC Assessment for Three- and Four-loop Plants	21.A-13
21.A.3.2 Westinghouse DVI Assessments	21.A-14
21.A.4 Plant Nodalization (CSAU Step 8)	21.A-16
21.A.5 Code/Experiment Accuracy (CSAU Step 9)	21.A-17
21.A.5.1 Westinghouse Realistic LBLOCA Methodology Roadmap ...	21.A-18

	<u>Page</u>
21.A.5.2 Models - Global Effects	21.A-20
21.A.5.3 Plant Conditions - Global Effects	21.A-21
21.A.5.4 Local Effects Models/Parameters	21.A-21
21.A.5.5 WCOBRA/TRAC Experiment Based Uncertainty	21.A-22
21.A.5.6 Other Parameters/Factors Considered by Westinghouse	21.A-22
21.A.5.7 Review of Uncertainty Propagation	21.A-23
21.A.6 Effects of Scale (CSAU Step 10)	21.A-23
21.A.7 Reactor Input Parameters/State (CSAU Step 11)	21.A-25
21.A.7.1 Westinghouse's Methodology	21.A-25
21.A.7.2 Review Summary	21.A-27
21.A.8 Additional Method Description and Review	21.A-27
21.A.8.1 LBLOCA Method Description/Review — Code Selection	21.A-28
21.A.8.2 LBLOCA Method Description/Review — Uncertainty Distributions and Assumptions	21.A-28
21.A.8.3 LBLOCA Method Description/Review — Split Breaks	21.A-32
21.A.8.4 LBLOCA Method Description/Review — Westinghouse HOTSPOT Model	21.A-33
21.A.8.5 Summary of Review	21.A-33
21.A.9 Comparison with Regulatory Guide 1.157	21.A-34
21.A.9.1 Summary of Westinghouse Methodology/RG 1.157 Comparison	21.A-34
21.A.9.2 WCOBRA/TRAC Range of Conditions/Applicability	21.A-35
21.A.10 Other Technical Issues	21.A-37
21.A.10.1 WCOBRA/TRAC CCFL Modeling Assessment	21.A-37
21.A.10.2 Compensating Errors	21.A-38
21.A.11 Compliance with 10 CFR 50.46 Requirements	21.A-39
21.A.12 Conclusions and Limitations	21.A-43
Appendix 21.B Safety Evaluation of AP600 Quality Assurance Inspections	21.B-1
21.B.1 QA Requirements for AP600 Design Certification Testing Activities	21.B-1
21.B.1.1 Core Makeup Tank Test Program	21.B-2
21.B.1.2 Automatic Depressurization System Test Program	21.B-3

	<u>Page</u>
21.B.1.3 Passive Residual Heat Removal Heat Exchanger Test Program	21.B-5
21.B.1.4 OSU/APEX Test Program	21.B-6
21.B.1.5 SPES-2 High-Pressure, Full-Height Integral Systems Test Program	21.B-9
21.B.1.6 Large-Scale Passive Containment Cooling System Test Program	21.B-10
21.B.2 Summary	21.B
22. REGULATORY TREATMENT OF NON-SAFETY SYSTEMS	22-1
22.1 Introduction	22-1
22.2 Scope and Criteria for the RTNSS Process	22-4
22.3 Specific Steps in the RTNSS Process	22-4
22.3.1 Comprehensive Baseline Probabilistic Risk Assessment	22-4
22.3.2 Search for Adverse Systems Interactions	22-5
22.3.3 Focused PRA	22-5
22.3.4 Selection of Important Non-Safety-Related Systems	22-6
22.3.5 Non-Safety-Related System Reliability/Availability Missions	22-6
22.3.6 Regulatory Oversight Evaluation	22-7
22.4 Other Issues Related to RTNSS Resolution	22-7
22.5 NRC Review of Westinghouse's Evaluation of Systems for Inclusion in RTNSS	22-7
22.5.1 Focused Probabilistic Risk Assessment	22-8
22.5.2 Containment Performance Consideration	22-12
22.5.3 Seismic Consideration	22-13
22.5.4 Deterministic ATWS and SBO Evaluation	22-13
22.5.5 Evaluation of Adverse Systems Interactions	22-14
22.5.6 Post-72-Hour Actions and Equipment	22-16
22.5.7 Mission Statements and Regulatory Oversight of Important Non-Safety-Related SSCs	22-17
22.5.8 Technical Specifications	22-19
22.5.9 Short-Term Availability Controls	22-19
22.6 Quality Assurance and Reliability Assurance Programs	22-20
23 REVIEW BY THE ADVISORY COMMITTEE ON REACTOR SAFEGUARDS	23-1
24 CONCLUSIONS	24-1

APPENDICES

A - Chronology	A-1
B - References	B-1
C - Abbreviations	C-1
D - Principal Contributors	D-1
E - Chronology of NRC's Requests for Additional Information	E-1
F - Combined License Action Items	F-1
G - Report by the Advisory Committee on Reactor Safeguards	G-1

FIGURES

1.2-1 AP1000 Reactor Coolant System	1-19
1.2-2 AP1000 Passive Safety Injection System Post-LOCA, Long Term Cooling	1-20
1.2-3 AP1000 Passive Containment Cooling System	1-21
1.2-4 AP1000 Safety Injection Systems	1-22
1.2-5 AP1000 Plant Layout	1-23
15.2.7.6 Pressure Drop vs. Core Steaming	15-90
15.3.6-1 Uncertainty Bands for Aerosol Removal Coefficients	15-105
19.1-1 Breakdown of Containment Release Frequency Based on the Level 2 PRA Results Reported by Westinghouse (Baseline PRA, Internal Events)	19-246
19.1-2 Breakdown of AP1000 Containment Release Modes by Contributor, as Reported by Westinghouse	19-247
19.1-3 Overall Dose Risk Site Boundary Whole Body EDE, 24-Hour Dose	19-248
21.6.5-1 Westinghouse Passive Containment Cooling Design	21-281
21.6.5-2 Historic Development of the GOTHIC Code	21-282
21.6.5-3 Development of WGOTHIC	21-283
21.6.5-4 Simplified Representation of a Clime Heat Structure	21-284
21.6.5-5 LOCA Time Phases	21-285
21.A-1 AP600 Peak Cladding Temperature Transient for the AP600 CD = 0.8 DECLG Break	21.A-51
21.A-2 CD = 0.8 DECLG Transient, Accumulator Flow Rate From One Tank	21.A-52
21.A-3 CCTF Run 58, Medium-Powered Rod, Clad Temperature Comparison at 6 ft .	21.A-53
21.A-4 CCTF Run 58, Medium-Powered Rod, Clad Temperature Comparison at 8 ft .	21.A-53

	<u>Page</u>
21.A-5 CCTF Run 58, Medium-Powered Rod, Clad Temperature Comparison at 10 ft	21.A-54
21.A-6 CCTF Run 58, High-Powered Rod, Clad Temperature Comparison at 6ft	21.A-54
21.A-7 CCTF Run 58, High-Powered Rod, Clad Temperature Comparison at 8 ft . . .	21.A-55
21.A-8 CCTF Run 58, High-Powered Rod, Clad Temperature Comparison at 10 ft . .	21.A-55
21.A-9 CCTF Run 58, Quench Envelope Comparison - Low-Powered Rod	21.A-56
21.A-10 CCTF Run 58, Quench Envelope Comparison - Medium-Powered Rod	21.A-56
21.A-11 CCTF Run 58, Quench Envelope Comparison - High-Powered Rod	21.A-57
21.A-12 CCTF Run 58, Upper Plenum Pressure Comparison	21.A-58
21.A-13 CCTF Run 58, Downcomer Differential Pressure Comparison	21.A-59
21.A-14 CCTF Run 58, Core Differential Pressure Comparison	21.A-60
21.A-15 CCTF Run 58, Loop 1 Cold Leg Steam Mass Flow Comparison	21.A-61
21.A-16 CCTF Run 58, Loop 1 Hot Leg Water Mass Flow Comparison	21.A-62
21.A-17 CCTF Run 58, Loop 1 Hot Leg Steam Mass Flow Comparison	21.A-63
21.A-18 CCTF Run 58, Loop 4 Hot Leg Water Mass Flow Comparison	21.A-64
21.A-19 CCTF Run 58, Loop 4 Hot Leg Steam Mass Flow Comparison	21.A-65
21.A-20 Breakdown of Westinghouse's Uncertainty Parameters	21.A-66
21.A-21 Flow Chart of Monte Carlo Procedure (AP600)	21.A-67

TABLES

3.9-1 Margins for Straight Pipe	3-293
6.2-1 Comparison of AP600/AP1000 Containment Design Features	6-11
6.2-2 Containment Initial Condition	6-18
6.2-3 PCS Flow Rates and Area Coverage	6-18
6.2-4 Summary of Calculated Pressures and Temperatures for a LOCA and an MSLB Using WGOthic 4.2	6-20
6.2-5 Postulated Breaks and Subcompartment Design Pressures	6-26
9.4-1 HVAC System Components	9-86
15.3-1 Staff-Calculated Radiological Consequences of Design-Basis Accidents (Total Effective Dose Equivalent (TEDE))	15-91
15.3-2 Assumptions Used to Evaluate the Radiological Consequences of the Main Steamline Break Accident Outside Containment	15-92
15.3-3 Assumptions Used to Evaluate the Radiological Consequences of the Reactor Coolant Pump Shaft Seizure Accident (Locked Rotor)	15-93
15.3-4 Assumptions Used to Evaluate the Radiological Consequences of the Rod Ejection Accident	15-94
15.3-5 Assumptions Used to Evaluate the Radiological Consequences of the Small Line Break Outside Containment Accident	15-96
15.3-6 Assumptions Used to Evaluate the Radiological Consequences of the Steam Generator Tube Rupture Accident	15-97

	<u>Page</u>
15.3-7 Assumptions Used to Evaluate the Radiological Consequences of the Loss-of-Coolant Accident	15-98
15.3-8 Aerosol Removal Rates Used by Staff to Evaluate Loss-of-Coolant Accident	15-99
15.3-9 Assumptions Used to Evaluate the Radiological Consequences to Control Room Operators Following a Design-Basis Accident	15-100
15.3-9a Atmospheric Dispersion Factors (χ/Q) for Control Room Habitability Accident Dose Analysis	15-102
15.3-10 Assumptions Used to Evaluate the Radiological Consequences of a Fuel-Handling Accident	15-103
15.3-11 Assumptions Used to Evaluate the Radiological Consequences of Spent Fuel Pool Boiling	15-104
15.3.6-1 Aerosol Removal Coefficients as Calculated by Uncertainty Analysis (hr-1)	15-105
19.1-1 Comparison of Core Damage Frequency Contributions by Initiating Event (Internal Events and Power Operation)	19-241
19.1-2 Level 1 Accident Class Functional Definitions and Core Damage Frequencies	19-242
19.1-3 Conditional Containment Failure Probability by Accident Class	19-243
19.1-4 Containment Release Categories and Associated Frequencies	19-244
19.1-5 Contribution to Risk from Various Release Categories, as Reported by Westinghouse (72-Hour Mission Time)	19-245
20.1-1 USIs/GSIs in NUREG-0933 (Supplement 25) relevant to the AP1000 Design	20-4
20.6-1 10 CFR 52.47(a)(1)(ii) TMI Action Plan Items	20-111
20.7-1 Resolution of Applicable Bulletins Issued between January 1, 1980, and December 31, 2002, for the Westinghouse AP1000 Design	20-116
20.7-2 Resolution of Applicable Generic Letters Issued between January 1, 1980, and December 31, 2002, for the Westinghouse AP1000 Design	20-134
21.3.6-1 Modifications to APEX for AP1000 Test Program	21-17
21.3-1 Wind Tunnel Test Phases 1 and 2 Matrix	21-21
21.3-2 Wind Tunnel Test Phase 4A Matrix	21-23
21.3-3 Large-Scale Test (LST) Facility Instrumentation	21-28
21.3-4 Large-Scale Tests and Target Conditions	21-29
21.3-5 Summary of Phases 1 through 3 Water Distribution Tests	21-33
21-1 Major Differences Between AP1000 and AP600 Designs	21-256
21-2 Non-LOCA Transients To Be Analyzed Using LOFTRAN	21-258
21-3 Double-Ended DVI Line Break Comparison Chart	21-259
21.6.5-1 Comparison of Containment Codes	21-260
21.6.5-2 Comparison Between WGOthic and CONTEMPT Interfacial Heat and Mass Transfer for Lumped-Parameter Modeling	21-261
21.6.5-3 Comparison of Correlations for Heat Transfer, Condensation, and Evaporation Implemented in WGOthic and CONTEMPT-LT/028	21-262
21.6.5-4 Clime Heat Transfer Correlations	21-263
21.6.5-5 Evaluation of Conservatism in Evaporated-Flow Model	21-264

	<u>Page</u>
21.6.5-6 Phenomena Identification and Ranking According to Effect on Containment Pressure	21-265
21.6.5-7 Summary and References for Treatment of High/Medium-Ranked Phenomena	21-269
21.6.5-8 Heat and Mass Transfer Parameters—Operating Range for AP600 and AP1000 (from Table 3-3, WCAP-15862, “WGOthic Application to AP600 and AP1000,” April 2002, Nonproprietary)	21-274
21.6.5-9 WGOthic Analyses of LST Using Lumped-Parameter Modeling Approach ..	21-275
21.6.5-10 Conservative Input Values for EM for Environmental (Outside Containment) Initial Conditions	21-276
21.6.5-11 Conservative Input Values for EM for Inside Containment Initial Conditions ..	21-277
21.6.5-12 Conservative Input Values for EM for Primary System and Secondary System Conditions	21-278
21.6.5-13 Conservative Input Values for EM for Primary PCS Characteristics	21-279
21.6.5-14 Conservative Input Values for EM for Geometry and Flow Characteristics ...	21-280
21.A-1 Westinghouse AP600 LBLOCA PIRT with Comparisons to the CSAU LBLOCA PIRT and Westinghouse's Three- and Four-Loop Plant LBLOCA PIRT	21.A-47